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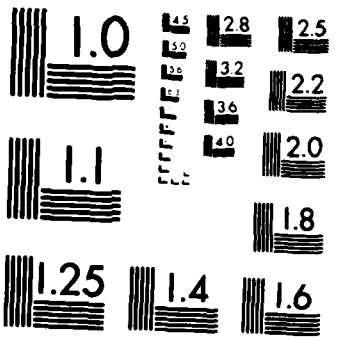

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) AFOSR-TR- 84-1269
6a. NAME OF PERFORMING ORGANIZATION Columbia University 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Air Force Office of Scientific Research
6c. ADDRESS (City, State and ZIP Code) Dept of Mechanical Engineering, Box 20, Low Memorial Library, New York NY 10027	7b. ADDRESS (City, State and ZIP Code) Directorate of Mathematical & Information Sciences, Bolling AFB DC 20332-6448
8a. NAME OF FUNDING/SPONSORING ORGANIZATION AFOSR 8b. OFFICE SYMBOL (If applicable) NM	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER AFOSR-82-0245
8c. ADDRESS (City, State and ZIP Code) Bolling AFB DC 20332-6448	10. SOURCE OF FUNDING NOS. PROGRAM ELEMENT NO. 61102F; PROJECT NO. 2304; TASK NO. A1; WORK UNIT NO.
11. TITLE (Include Security Classification) PRACTICAL CONSIDERATIONS FOR NONINTERACTING CONTROL SYNTHESIS	
12. PERSONAL AUTHOR(S) George Klein	
13a. TYPE OF REPORT Final 13b. TIME COVERED FROM 1/10/83 TO 30/9/84	14. DATE OF REPORT (Yr., Mo., Day) 30 OCT 84 15. PAGE COUNT 3
16. SUPPLEMENTARY NOTATION	
17. COSATI CODES FIELD / GROUP / SUB. GR.	18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Decoupling control; eigenstructure assignment; deadbeat control.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The research was concerned with the practical problems of achieving noninteracting control (decoupling). This problem involves finding a feedback controller so that each input of a system affects one and only one output of the closed-loop system and maintains this behavior even in the presence of small modelling errors. This research then led to the investigation of the problem of determining the freedom in assigning eigenstructures when the closed-loop system has repeated eigenvalues. The research results for the problem of noninteracting control has led to a characterization of the closed-loop eigenstructure of decoupled systems. The results of the investigation of the second problem has led to a complete characterization and better understanding of the minimum time control of discrete time systems, better known as deadbeat control systems.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL MAJ Brian W. Woodruff	22b. TELEPHONE NUMBER (Include Area Code) (202) 767- 5027 22c. OFFICE SYMBOL NM

AFOSR-TR- 84-1269

Final Report On
Practical Considerations for
Noninteracting Control Synthesis

Problem Statement

The original problem that was to be examined was concerned with investigating some of the practical considerations necessary to achieve decoupling or noninteracting control of a multi-input multi-output (MIMO) system. For a linear system with m independent inputs and p independent outputs modelled by

$$\dot{x} = A\,x + Bu$$

$$y = C_i x \qquad i \in \underline{p}$$

$$(\underline{p}=1,2,\ldots,p)$$

the problem becomes that of controlling the system so that the i th input (or combination of inputs) excites only the i th output without affecting the others. The approach generally taken [1-8] has been to find a state feedback matrix F and input reordering matrices G_i, $i \in \underline{m}$ such that for the closed-loop system

$$\dot{x} = (A+BF)x + \sum BG_i\, u_i$$

$$y_i = c_i x \quad i \in \underline{p}$$

input u_i only affects output y_i. The proposed research was intended to examine approaches to select the $[G_i,\ i \in \underline{m}]$ and F to reduce the level of interactions that innvariably result in the presence of modelling errors in the system parameters (A,B,C).

The approach that was used involved the study of controllability subspaces, subspaces that are spanned by closed-loop eigenvectors. A key problem that was quickly encountered was the amount of freedom available in selecting these eigenvectors considering the overlap in the controllability

subspaces. This problem proved to be more difficult and interesting than was initially expected and took up the majority of research time.

Status of Research

As described in the previous section the research problem evolved into two related problems; one problem involving the investigation of the sensitivity of noninteracting control systems and a second problem involving the detailed examination of the available freedon in selecting closed-loop eigenstructures when the system has repeated eigenvalues. The solution of the former problem was found to be dependent on the latter.

Preliminary theoretical work and software development has been completed on the problem of decoupling controller design. This work is summarized in [9] and is included as Appendix 1. The approach was based on developing eigenstructure characterizations of closed-loop systems that are decoupled and then using modified versions of previously developed techniques to assign these eigenstructures in a robust or insensitive manner. The current research has provided a characterization of the decoupled eigenstructure for the case involving distinct eigenvalues (generic) with equal numbers of inputs and outputs and no transmission zeros in the right half-plane. Some preliminary work has been completed on the remaining cases involving repeated eigenvalues, more inputs than outputs and arbitraty numbers of transmission zeros located anywhere in the complex plane. It is intended to pursue this line of research in the future.

The problem of characterizing the freedom in selecting closed-loop eigenstructure involving repeated eigenvalues led to the second research problem that was investigated. The results of this work is summarized in [10,11] (included in the appendix) and in an additional publication based on [11] still in preparation. This work has provided a characterization of the closed-loop eigenstructures that can be assigned when there are repeated eigenvalues. These results were applied to the problems of minimum time

control of discrete time systems since this problem involves assigning all the closed-loop eigenvalues to zero. All the available freedom in selecting these so called deadbeat controllers was described and an analytic expression for the controller of minimum Frobenius norm was derived for the canonical eigenstructure. This work is also being pursued further and provides some extremely exciting possibilities. One area being investigated is the development of simple time-optimal controllers for discrete-time models that take into account the magnitude constraints on the inputs. Without using dynamic or linear programming it appears possible to develop such controllers without extensive calculations. The importance of such a result and the number of applications would be hard to overstate.

Publications Resulting from the Research

The following publications were due to the effort of G. Klein exclusively and were the result of the research performed for the U.S. Air Force under Grant AFOSR-82-0245:

G. KLEIN, "Robust Noninteracting Controller Design", 1983 American Control Conf.

G. Klein, "On the Relationship Between Controllability Indices, Eigenvector Assignment, and Deadbeat Control", IEEE Trans. Automatic Control, Vol. AC-29, pp 77-79, Jan. 1984.

G. Klein, "The Freedom in Selecting the Eigenstructure of Deadbeat Controllers", Invited Paper, 1985 American Control Conf.

G. Klein, "The Eigenstructure of Deadbeat Control Systems", in preparation, to be submitted to IEEE Trans. Aut. Control or Syst. Control Letters.

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